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A Framework for Avoiding Uncanny Valley in Healthcare

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ABSTRACT:
The advancement in robotics has led to the increase in the demand for robots in healthcare for surgical procedures, rehabilitation, therapy, sanitation, sterilization and material handling. Hence, robots are used in the healthcare system to increase the safety of both patients and healthcare professionals, enhance clinical outcomes, reduce the cost of healthcare services and create a sense of stability and calmness for the sick and the aged. Robots are designed in various sizes and shapes to accomplish a particular task. For instance, some healthcare robots are designed to possess the overall appearance of a human body, imitate human intelligence, emotional responses, behavior as well as maneuverability. These types of robots are referred to as humanoid robots. The human-like appearances of humanoid robots facilitate the natural interaction between them and humans. However, when humanoid robots appear almost like human beings and there is a disparity between their behavior and their appearances, a feeling of repulsion is created amongst its users. This situation is referred to as uncanny valley which is usually viewed as a threat to the uniqueness exhibited by human beings. Consequently, the social acceptance of humanoid robots within the context of healthcare becomes a challenge because the effective interaction between humans and such robots is hindered. This results in a decline in the quality of health services that are rendered by humanoids robots. Hence, this study takes a critical examination at humanoid robots used in healthcare, the concept of uncanny valley as well as the hypothesis of uncanny valley. The study also appraises the effects of uncanny valley in relation to the healthcare system and designs a framework for avoiding the uncanny valley in healthcare during the design of humanoid robots.
Keywords: anthropomorphism, healthcare, humanoid robot, uncanny valley

INTRODUCTION:

The rapid innovation in robotics has created new ways of managing patients health within the healthcare system. For instance, robots are now used for providing therapy, rehabilitation, assistance for the decreasing numbers of healthcare employees, entertainment and companionship to patients in healthcare [1]. Robots have also been widely used to assist in surgical operations. Hence, the use of robots in healthcare has the potential of reducing medical errors, reducing the cost of healthcare, creating a sense of stability and calmness for the sick and the aged and dramatically improving the delivery and quality of healthcare services. Healthcare robots come in diverse sizes, shapes, appearances or morphology. Fong et al. [2] classified robots based on their appearances into four categories. These include zoomorphic, anthropomorphic, functional as well as caricatured robots. Zoomorphic robots according to Fong et al. [2] are robots that take the appearances of animals. Anthropomorphic robots are robots that take the form of human beings. In addition to taking the forms of human beings, anthropomorphic robots also imitate human intelligence, emotional responses, behavior as well as maneuverability. According to Feil-Seifer and Matari´c [3], anthropomorphic robots enhance interaction between humans and robots. Hence, human beings are more familiar with robots that are anthropomorphic in nature. Nonetheless, robots that take the shape and possess the qualities of human beings are referred to as humanoid robots. Functional robots according to Yanco and Drury [4] are robots that neither takes the form of animals nor human beings while caricatured robots are robots that are specific representations of particular animals or human beings. Hence, caricatured robots are simply stereotypical representations of a particular animal or person [4].

Humanoid robots are usually designed to perform specific tasks in a particular environment or society. Nevertheless, the human environment consists of sets of relatively strict rules which the robot must adhere to. However, when the appearance of humanoid robots becomes increasingly human-like, they become more familiar and attractive to their users and thus the users have an increasingly positive response towards the robots. This is because humans tend to like other human beings [5]. Nonetheless, as the features of the humanoid robots become more human like, the expectation is that the robot should behave in consonance with the set of rules in its environment. For instance, an abnormality looking eyes of a humanoid robot and its mechanical movement might be negatively interpreted and considered inadequate in a particular environment because of the mismatch between the appearance of the robot and its behavior [6]. Therefore, the violation of certain environmental rules by a humanoid robot is considered as a faux pas which can ultimately create a sense of strangeness, unpleasant impressions, disturbing and negative feelings for the robots. Such feelings include unattractiveness, fearfulness, ugliness, abnormality, sickness and inelegance and these represent a threat to the uniqueness of human beings. Hence, the point at

which the feelings for a robot changes from empathy or affinity to repulsion or aversion is referred to as uncanny valley [7].

The uncanny valley can be described as a phenomenon which emphasizes that human characteristics or features in a robot can cause uneasiness in human beings. At the point of uncanniness, the social acceptance of the humanoid robot declines and this ultimately decreases the quality of healthcare services delivered to patients in the healthcare system. Furthermore, the phenomenon of uncanny valley is still not well-understood in the field of human-robot interaction [8]. Hence, this study examines the concept and theories underlying uncanny valley as well as its impacts on the healthcare system. This study also designs a framework for avoiding the uncanny valley in healthcare.

AN OVERVIEW OF HUMANOID ROBOTS IN HEALTHCARE

Humanoid robots according to Behnke [9] are robots with an anthropomorphic body plan and human-like senses. Hence, a humanoid robot resembles and acts like a human being. Saxena and Bhargava [10] emphasized that humanoid robots have a torso or trunk with a head, two arms as well as two legs. However, humanoid robots may either possess the full body of human beings or some parts of the human body such as from the waist up. Humanoid robots may also have human facial features such as eyes, nose, mouth and eyelids [11]. Hence, Fussell et al. [12] emphasized that for a robot to be tagged humanoid, it must have a body that resembles a human and it must also act like a human. According to Breazeal [13], humanoid robots can communicate naturally with the communication modalities of humans such as facial expression, body posture, gesture, gaze direction and voice. They are designed to imitate human intelligence, emotional responses, behavior and maneuverability. Humanoid robots come in diverse sizes and shapes which could be in form of human-size legged robots, isolated robotic heads and they could also be in the form of a human with a head and two arms mounted on a stationary torso [14]. Moreover, when a humanoid robot becomes indistinguishable in its appearance from humans, it is referred to as an android [15]. Examples of features that humanoid robots possess that are inherent in humans include the following:

1. Locomotion

Locomotion refers to the ability to move in an environment. One major characteristic of humanoid robots is their ability to move from one place to the other. Humanoid robots with legs can walk, crawl under an obstacle, lean unto something, pull with the weight of their body and change their postures [16]. Other movements performed by humanoid robots include running, rolling on wheels, bipedal walking, hopping and propelling by thrusters. The rotary actuators are majorly responsible for human-like motions in humanoid robots. However, humanoid robots still have serious challenges with walking and running on two legs [9].

2. Manipulation

Another major attribute of human beings exhibited by humanoid robots is dexterous manipulation. Manipulation refers to the ability of the hands to perform a specific task in an environment. Dexterous manipulation typically involves the use of anthropomorphic arms, hands, and sensors to perform tasks that are commonly performed by people. Hence, just like humans, humanoid robots can grasp objects in an environment. Manipulation tasks usually performed by humanoid robots include lifting, carrying, picking, pushing, pouring, stirring, brushing, crank turning, hammering, and sawing.

3. Communication

Humanoid robots have the ability to establish and maintain social relationships with human beings using natural cues like auditory speech, text-based responses, haptics, gaze and gestures such as hand and facial movements [17]. Humanoid robots hands and arms can be used for gestures in addition to reaching and grasping. Some humanoid robots engage in conversational speech using face tracking, face recognition, speech recognition and speech synthesis which is achieved using Artificial Intelligent driven software. Humanoid robots can also express and perceive emotions which provide feedback to the humans they are interacting with. The head and eyes of a humanoid robot can be used to make expressive poses along with the rest of the body [14]. In addition, for humanoid robots to effectively communicate with human beings, they must possess some features that will enable them to perceive the world as humans [18]. Such features include the use of two cameras in place of the two eyes. These cameras serve as the active vision system of the humanoid robot thereby helping them to focus on relevant objects in the environment. Humanoid robots also make use of two microphones which serve the purpose of the human ears.

4. Learning

Humanoid robots can easily adapt, perceive, recognize and learn new behaviors or skills by imitation or through natural means. Imitation learning involves the ability of robots to learn from capable teachers or humans in their environment [19]. Like humans, humanoid robots also have the ability to learn or acquire new skills by demonstration.

Fig. 1. Autom, the weight loss coach [21]

Fig. 2. Nao [23]

Fig. 3. Pepper interacting with a friend [23]

Fig. 4. Pearl [24]

Fig. 5. Bandit [25]

Fig. 6. A receptionist robot [26]

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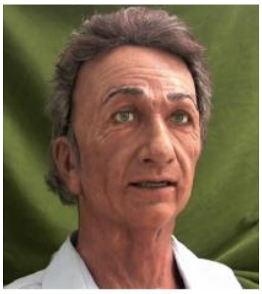

Fig. 7. Charles [21]

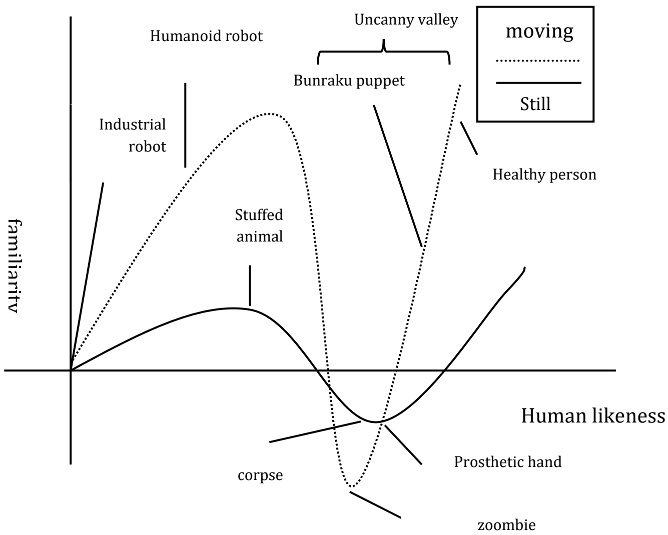

Fig. 8. A graph of the uncanny valley [37]

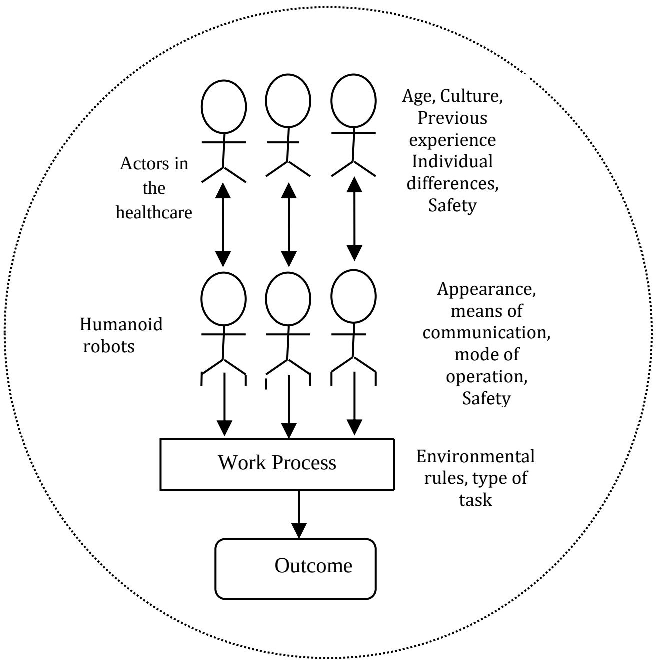

Fig. 9. The Proposed Framework

5. Sensing
A humanoid robot has the ability to sense its environment just like humans. A humanoid robot also reacts and adapts to changing conditions in its environment with the aid of sensors. The sensors also aid a humanoid robot to detect objects or features in its environment.

Humanoid robots have been used in healthcare to assist the aged and the sick; they have also been used in therapeutic settings and they have been successfully deployed to improve communication skills in children with developmental disabilities such as dementia patients. This is because they can easily repeat instructions without becoming tired. Humanoid robots provide emotional care and companions for older individuals who might be lonely. Typical examples of humanoid robots used in healthcare include:

1. Autom
Autom, the weight loss coach is a humanoid robot designed by Kidd and Breazeal [20]. The aim of the robot is to encourage weight loss amongst children and adults. This is with a view to reducing diseases related to obesity and overweight such as Type 2 diabetes mellitus, heart disease, high blood pressure, and some cancers [20]. Fig 1 shows the picture of Autom, the weight loss coach.

2. Nao
Nao, a small sized humanoid robot developed by Diehl et al. [22] has been deployed in retirement homes for exercises and movement programs. It has also been used to provide companionship for the aged who are lonely. Nao robot is less than two feet tall but it is mobile, agile and pleasant [23]. The Nao robot is as shown in Fig 2.

3. Pepper
Pepper is a four feet humanoid robot developed by Softbank to improve the mental engagement of humans by reading and responding to their emotions [23]. Pepper is a quite engaging robot that has been used for providing therapy and emotional care to patients. Pepper is specifically designed to enhance natural human interaction through speech and touch gestures. Hence, Kefee [23] emphasized that Pepper's skills in human-robot interaction has helped to improve the emotional and mental needs of patients. Fig 3 shows the picture of Pepper interacting with a friend.

4. Pearl
Pearl is a humanoid robot that was developed in 1998 by a multidisciplinary team of healthcare and Computer Science investigators as a part of the Nursebot project [24]. Pearl has two primary functions. These include assisting elderly people with mild impairments such as memory lapses with routine activities like eating, drinking, taking medicine, as well as using the bathroom, and guiding them through their environments. Fig 4 shows the picture of Pearl.

5. Bandit
Bandit is a humanoid robot developed by University of Southern California (USC) Center for Robotics and Embedded Systems. Bandit according to the Institute for the Future [25] provides social cognitive support for the elderly by engaging them in various cognitive tasks such as solving puzzles, responding to questions and playing music. Bandit is also used for providing therapy to children with autism. Bandit is shown in Fig 5.

6. ***Receptionist robot***
A receptionist robot is used in a healthcare setting to register an appointment with a physician and they also help with check-in or check-out formalities thereby reducing the waiting time of the patients [26]. They are also used to direct patients to the right locations within the hospital environment. Receptionist robots are deployed in hospitals in Belgium and Japan [26]. Fig 6 shows a typical receptionist robot.

7. Charles
Robot Charles as shown in Fig 7 is a healthcare robot developed by Riek and Robinson [27]. Robot Charles is a therapy robot used to help medical practitioners in the treatment of people with developmental disabilities such as dementia, autism, and cognitive impairments.

THE UNCANNY VALLEY
The term uncanny valley, which is an English translation of the Japanese word **"不気味の谷現象"** (bukimi no tani), is a term used to describe a situation when a person has a strange, scary and familiar feelings simultaneously towards human-like objects [8]. The human-like objects in this regard refers to robots, dolls, masks, facial caricatures, avatars in virtual reality, mannequins, prosthetic hands and characters in computer graphic movies [28]. The term uncanny valley was coined by Masahiro Mori in 1970 to describe a situation whereby a person has a positive feeling towards increasingly human-like robots until a point is reached, when this feeling turns into repulsion [29]. Mori et al. [29] also emphasized that as robots appear more human-like, the affinity for humanoid robots increases and hence the social acceptance of such robots is also increased. This is because human beings tend to love themselves. However, when the appearance of the robot becomes increasingly more human, the feeling of affinity turns into un-canniness or unpleasant impressions.

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MacDorman and Ishiguro [15] supported Mori's [7] uncanny valley theory by carrying out a study on human likeness, familiarity, and eeriness on two sets of morphed photographs which included a humanoid robot, an android and a human. MacDorman and Ishiguro [15] found out that the familiarity rating for the photographs between the humanoid robot and the android was accompanied by an increase in strange feelings. Seyama and Nagayama [30] however observed that uncanny valley occurs at a point when there is a slight deviation between the appearance of a human-like robot and the behavior of the robot, which breaks the illusion of human-likeness. For instance, uncanny valley will occur when a humanoid robot has a perfectly realistic human appearance and the robot exhibits abnormal features such as bizarre eyes and mechanical movement. However, Hanson [31] is of the view that the uncanny valley is simply an emotional reaction that may be subject to change over time.

Mori [7] plotted a graph of familiarity against human likeness or the dimension of anthropomorphism for still and moving human-like objects. From the graph, it can be deduced that the level of impression or familiarity is zero for robots which do not have any resemblance with human beings. A typical example of this kind of robot is the industrial robots. However, the familiarity level is very high for robots with perfectly realistic human appearance [29]. Hence, as the appearance of the robot increasingly resembles a person, its familiarity increases until it gets to a point where the familiarity level becomes negative and a strong feeling of repulsion or un-canniness is created. This negative response to humanoid robots appeared as a large valley in the middle of the two peaks on either side of the graph in Fig 8 [32]. Moreover, Pollick [33] and Mone [34] emphasized that the valley is more deepened in a moving robot because the robot is rejected if there is a mismatch between the appearance of the robot and its movement. Moreover, MacDorman [35] is of the view that the appearance of robots in the context of uncanny valley does not only include anthropomorphism but also other senses like the sense of touch and smell, quality of movement and voice, speech, prosody, and other aspects of continuity like interactivity and timing. However, Mori's [7, 29] theory of uncanny valley according to Pollick [33] is short termed and spontaneous and can be overcome by habituation. The graph of the uncanny valley is as shown in Fig 8. The uncanny valley is however a contentious theory that has generated a lot of controversies. For instance, Bartneck et al. [36] is of the view that the theory of uncanny valley is too simple and not well defined and the theory do not consider the age, culture, religion, or the previous experiences of the users of the robots.

HYPOTHESIS OF UNCANNY VALLEY

Quite a number of authors have formulated diverse theories on the issue of uncanny valley. Some of these theories are reviewed in this section.

1. *Mortality salience hypothesis*

The mortality salience hypothesis was inspired by Terror Management Theory in social psychology and was formulated by Sara Kiesler [38]. According to Wang et al. [39], the hypothesis states that some human replicas are uncanny because they remind people of death and trigger defense systems that cope with anxiety for mortality. Thus, the uncanny valley triggers the fear of death, replacement and annihilation in human beings.

2. *Dehumanization hypothesis*

According to Wang et al. [39], dehumanization is the ability to perceive a person or group of people as lacking humanness. Hence, dehumanization means to deprive human beings of human qualities. In anthropomorphism, humanoid robots usually possess human-like features such as eyes, emotional expressions, voice and movements. These features are usually mechanical and unemotional in nature, thereby serving as threats to the uniqueness of human beings and hence the feeling of uncanniness sets in.

3. *Violation of expectation hypothesis*

The Violation of Expectation hypothesis states that human replicas will elicit the feeling of uncanniness when a humanoid object fails to meet the goal for which it was designed [40].

4. *Mind perception*

This theory of mind perception suggests that uncanniness does not only arise from the appearances of robots but attributing experiences or emotions and sensations to robots [41].

5. *Threat to human distinctiveness and identity*

Human beings are unique. However, the attribution of human characteristics or features to artificial and non-living entities is viewed by some people as a threat to the human identity and uniqueness of human beings [42]. Hence, the attribution of human-like features to humanoid robots is viewed by some as a threat to human identity, and this elicit negative responses towards the robot.

EFFECTS OF UNCANNY VALLEY IN HEALTHCARE

The healthcare system is primarily concerned with people's health. The primary purpose of a healthcare system is to promote, restore, and maintain health. Thus, the main goal of a healthcare system is to reduce medical errors and costs, improve healthcare efficiency, increase patients' safety as well as increase

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the quality and convenience of patients care [43]. However, the rising cost of healthcare, the exponential growth of vulnerable population such as the sick and the aged and the shortage of qualified healthcare professionals has resulted in the creation of new ways of managing patients within the healthcare system. One of the major ways of providing alternative care to patients in recent times is the use of robots which is fast becoming prevalent as a result of the advancement in robotics technology. However, robots in recent times have been designed to take the appearances of human beings. Humanoid robots are widely used in the healthcare system to perform several functions such as therapy, rehabilitation, entertainment and companionship. However, when the appearances of humanoid robots are too humanlike, the feeling of repulsion is created. Hence, this section reviews the effects of uncanny valley on the healthcare system.

1. *Fear of replacement*

One of the major effects of the uncanny valley in the healthcare system is that patients may have the feeling that their healthcare providers and other people within their environment have been displaced and replaced with robots. For instance, Ellis and Lewis [44] reported that patients suffering from Capgras syndrome felt that people in their environment were replaced by duplicates when humanoid robots were used in the care process. This feeling according to Ellis et al. [45] is naturally unsettling for the patients.

2. *Fear of mortality*

Quite a number of authors have argued that humanoid robots elicit the fear of mortality in humans [15, 46]. The healthcare system is a very sensitive domain that deals with matters of life and death. Moreover, the goal of the healthcare system is to improve the quality of healthcare services and also to preserve life. Hence, when the fear of mortality sets in, the humanoid robots or an android in the healthcare system will symbolize threats to the lives of patients.

3. *Low rate of acceptance*

Dillion [47] defines user acceptance as the demonstrable willingness within a user group to employ a technology for the tasks it is designed to support. The appearance of a robot is usually significant to its social acceptance. However, humanoids and androids represent threat to the uniqueness exhibited by human beings [48]. For instance, Pino et al. [49] emphasized that hyper-realistic representations of robots with human appearance could lead persons with dementia to confusion. Hence, the interaction between humans and humanoid robots is a challenge. Consequently, the social acceptance of humanoid robots within the context of healthcare becomes a challenge as patients may not be willing to have them in their environments.

THE FRAMEWORK FOR AVOIDING UNCANNEY VALLEY IN HEALTHCARE DURING THE DESIGN OF HUMANOID ROBOTS

Mori et al. [29] suggested that to avoid the uncanny valley, robots should not be designed too close to humans because they would elicit a repulsive reaction. Hence, most researchers consider the uncanny valley as a major factor during the design of humanoid robots [50]. However, this study supports the work of Bartneck et al. [36] which emphasized that in addition to considering the appearance of the robot during design, other factors such as the age, culture, previous experience, background, and individual differences of the robot users must be considered.

The major difference between the proposed framework and the suggestions made by Bartneck et al. [36] is that the framework considers the mode of operation of the robot, the type of task that the robot is designed to perform, the means of communication between the robot and the human beings, environmental rules as well as the safety of both the robots and the human beings in the design of humanoid robots for the healthcare system. The proposed framework is as shown in Fig 9. The proposed framework consists of four basic elements which include the actors, the humanoid robots, the work process and the outcome. To avoid uncanny valley in healthcare, all these elements must be considered simultaneously during the design of a humanoid robot. The elements of the proposed framework are discussed below.

1. *Actors*

The actors in the framework represent the people within the healthcare system. There are two basic actors in the healthcare system. These include the healthcare practitioners and the patients. The actors use the robots for performing specific tasks such as material handling, rehabilitation, companionship and therapy. The framework suggests that the ages, culture, previous experience, individual differences and the safety of the actors must be considered during the design of humanoid robots in healthcare. For instance culture refers to the ethnic, national or geographic location of the users of the robots. Culture involves the religion and language of a group of people. For instance, several researchers have found out that the way the Japanese interact with robots differs from the way the Europeans interact with them. Hence, the Japanese are usually more enthusiastic in the deployments of robots than the Europeans [51]. Individual differences refer to the variations in the psychology, attitude, interest, personality, intelligence

and values of the actors within the healthcare system. These differences in the characteristics of human beings make them unique. Hence, the actors in healthcare system will have diverse views on the use on humanoid robots for providing care. Experience refers to the knowledge of an event or subject gained through the exposure to the subject or event. Hence, the previous experience of the actors must be considered during the design of a humanoid robot because the more exposed they are to a humanoid robot, the more familiar they will be with the robot. Hence, their affinity will be built towards the use of humanoid robots.

2. Humanoid robots

In addition to the appearance of the robot, the robots mode of operation and the means of communication between the robot and the actors must also be considered. For instance, humans and robots interact in diverse ways such as the use of visual displays like graphical user interfaces or augmented reality interfaces, gaze and gestures such as hand and facial movements, speech and natural languages. However, these means of interaction between the robot and the actors must conform to the rules of the healthcare system in order to prevent faux pas. The mode of operation of the humanoid robot must also be recognized during the design of humanoid robots. Some humanoid robots are fully autonomous; some are semi-autonomous while others are teleoperated. For instance, humanoid robots that are fully autonomous may elicit fear that the healthcare providers have been displaced and replaced with robots. Hence, the fear of autonomous care is heightened amongst the patients. This loss of interpersonal contacts however reduces the attractiveness of the health profession. Hence, it is advised that humanoid robots or androids should not be designed to provide autonomous care in healthcare. Lastly, the safety of both the actors and the humanoid robots are also important factors that must be considered during the design of a humanoid robot. As a result of the sensitivity of the healthcare system, a humanoid robot must be designed to avoid obstacles, collision and fall while maneuvering in the hospital environment. A humanoid robot used in healthcare must also be designed to be fault tolerant; it must be designed in such a way that it degrades gracefully. For instance, humanoid robots that fail or malfunction too often during healthcare delivery process are harmful to the health of a patient. This elicits fear and threat in the patients thereby making the robots to fall into the uncanny valley.

3. Work process

The work process is the action performed by the different actors or humanoid robots within the healthcare system. It involves the environmental rules and the type of tasks the humanoid robots are designed to perform. The environmental rules are simply sets of instructions that both the actors and robots must obey during the performance of a task. Humanoid robots are usually designed for specific tasks within the healthcare system. For instance, some humanoid robots are designed to provide companionship for the elderly while some are specifically designed to provide social cognitive support for children with developmental disabilities. For instance, humanoid robots that are designed to provide companionship can be designed to maintain a close interaction with the patients. Interactions like touching and stroking can be encouraged between the robots and the users. This will make the companionship process more interesting and it will facilitate the success of the recovery process. However, humanoid robots that are designed to transport healthcare materials from one location to another need not be designed to have a close interaction with patients rather they should be designed to maintain a safe distance from patients. The humanoid robot must also be designed in such a way that there must be a relationship between the shape of the robot and the type of the task that the robot is designed for.

4. Outcome

The outcome is a condition that determines if the purpose or motive for which the humanoid robot was designed is met. For instance, if a humanoid robot efficiently achieves its goal in the healthcare system, its appearance will not be considered and the level of acceptance of the robot will be increased.

CONCLUSION

The uncanny valley is a theory proposed by Masahiro Mori a Japanese roboticist, in 1970. Mori described the uncanny valley as a situation whereby a person has a positive feeling towards an increasingly human-like robot until a point is reached, when this feeling turns into repulsion. However, quite a number of humanoid robots have been deployed in the healthcare system to perform tasks like rehabilitation, therapy, companionship and material handling. Humanoid robots are increasingly used within the healthcare system because of the exponential increase in the cost of healthcare and the shortage of healthcare personnel. Nevertheless, when there is a misfit between the behavior of a humanoid robot and its appearance, the robot falls into the uncanny valley. Hence, the level of acceptance of humanoid robots in the healthcare declines, and the delivery of quality healthcare services is hindered. Consequently, this study critically examines humanoid robots used in healthcare, the general concept of uncanny valley, the hypothesis of uncanny valley and the effects of uncanny valley on healthcare. The study also proposes a framework for

avoiding uncanny valley during the design of humanoid robots in healthcare. The study proposes that in addition to the appearance of the robot, other factors such as the type of task that the robot performs, the mode of operation of the robot and the safety must be considered during the design of humanoid robots. The study also corroborated the research of Bartneck et al. (2009) which emphasized that age, culture, previous experience, background, individual differences of the actors within the healthcare system must be considered during the design of humanoid robots. Furthermore, the framework suggests that four basic elements must be considered simultaneously during the design of humanoid robots in healthcare in order to avoid the uncanny valley. These elements include the actors, the humanoid robot, the work process and the outcome.

REFERENCES

[1] Onishi, M. (2006). In a wired South Korea, robots will feel right at home. In The New York Times.

[2] Fong, T. W., Nourbakhsh, I., & Dautenhahn, K. (2011). A survey of socially interactive robots: concepts, design, and applications. Robotics and Autonomous Systems, 42(3): 142-166.

[3] Feil-seifer, D. & Mataric, M.J. (2005). Defining socially assistive robotics. In: International Conference on Rehabilitation Robotics.

[4] Yanco, H.A. and Drury, J. (2004). Classifying human-robot interaction: an updated taxonomy. Systems, Man and Cybernetics, 3:2841-2846.

[5] Gauthier, I., Skudlarski, P., Gore, J.C. & Anderson, A.W. (2000). Expertise for cars and birds recruits brain areas involved in face recognition. Nature Neuroscience, 3(2): 191-197.

[6] Saygin, A.P., Chaminade, T., Ishiguro, H. Driver, J. & Frith, C. (2012). The thing that should not be: predictive coding and the uncanny valley in perceiving human and humanoid robot actions. Sociology Cognitive Affect Neuroscience, 7(4):413– 422.

[7] Mori, M. (1970). The uncanny valley. Energy, 7(4):33– 35.

[8] Pollick, F.E. (2010). In Search of the Uncanny Valley. [Proceedings of the 1st international conference on User Centric Media, Revised Selected Papers, 69-78].

[9] Behnke, S. (2008). Humanoid robots-from fiction to reality? KI-Zeitschrift, 4: 5-9.

[10] Saxena, S. & Bhargava, D. (2012). RoHeMaSys: medical revolution with design and development of humanoid for supporting healthcare. Amity Institute of Information Technology, Amity University Rajasthan, Jaipur, Rajasthan, India.

[11] Pino, M., Boulay, M. Jouen, F. & Rigaud A.S. (2015). Are we ready for robots that care for us?� Attitudes and opinions of older adults toward socially assistive robots. Frontiers in Aging Neuroscience, 7 (141): 1-15.

[12] Fussell, S.R., Kiesler,S., D.S. Leslie, & Yew, V. (2008). How people anthropomorphize robots. In: Human Robot Interaction, Amsterdam, Netherlands.

[13] Breazeal, C. (2002). Designing sociable robots. MA, MIT Press, Cambridge.

[14] Kemp, C. C., Fitzpatrick, P., Hirukawa, H., Yokoi, K., Harada, K. & Matsumoto. Y. (2006). Humanoids. Human-Centered and Life-Like Robotics, 1307-1333.

[15] MacDorman, K. F., & Ishiguro, H. (2006). The uncanny advantage of using androids in cognitive and social science research. Interaction Studies, 7(3): 297-337.

[16] Gutman, J., Fukuchi, M., & Fujita, M. (2008). Modular architecture for humanoid robot navigation. [Proceedings of 5th IEEE-RAS Int. Conf. Humanoid Robot, 26-31].

[17] Goodrich, M. A. & Schultz, A. C. (2007). Human– robot interaction: a survey. Foundations and Trends in Human– Computer Interaction, 1: 203-275

[18] Spexard, T., Haasch A., Fritsch, J. & Sagerer, G. (2006) Human-like person tracking with an anthropomorphic robot. [Proceedings of the IEEE International Conference on Robotics and Automation, 1286– 1292].

[19] Nakanishi, J., Morimoto, J., Endo, G., Cheng, G., Schaal, S. & Kawato, M. (2004).Learning from demonstration and adaptation of biped locomotion. Robotics and Autonomous Systems, 47 (3): 79– 91.

[20] Kidd, C. D. & Breazeal, C. (2008). Robots at home: understanding long-term human- robot interaction. In: IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).

[21] Riek, L. D. (2015). Robotics technology in mental health care. In: Artificial Intelligence in Behavioral Health and Mental Health Care, D. Luxton (Ed.), Elsevier.

[22] Diehl, J. J., Crowell, C. R., Villano , M., Wier, K., Tang, K. & Riek, L. D. (2014). Clinical applications of robots in autism spectrum disorder diagnosis and treatment. In: Comprehensive Guide to Autism, Springer, 411-422.

[23] Keefe, B. (2015). Robots/robotics in healthcare. In: Design, Experience and Innovation, Center for Innovation, Mayo Clinic.

[24] Pollack, M. E., Brown, L., Colbry, D., Orosz, C., Peintner B., Ramkrishnan, S., Engberg, S., Matthews, J., Dunbar, J.J., McCarthy, C., Thrun, S., Montemerlo, M., Pineau, J. & Roy N. (2002). Pearl: a mobile robotic assistant for the elderly. In AAAI Workshop on Automation as

Caregiver.

[25] Institute for the Future (2010). Robots in caring and healing roles. Health, Institute for the Future, 1-4.

[26] Tractica White Paper (2016). Utilizing humanoid robots for customer engagement: benefits and challenges, use cases and industry, verticals, and business considerations. Softbank Robotics, 1-31.

[27] Riek, L. D., & Robinson, P. (2011). Using robots to help people habituate to visible disabilities. In IEEE International Conference on Rehabilitation Robotics (ICORR), 1-8.

[28] Roberts, D. & Roberts, N.J. (2014). Clinical simulation: dare we venture into the uncanny valley? Nurse Education in Practice, 14:225-226.

[29] Mori, M., MacDorman, K. F., & Kageki, N. (2012). The uncanny valley. IEEE Robotics and Automation Magazine: 19(2), 98–100.

[30] Seyama, J. and Nagayama, R.S. (2007). The uncanny valley: effect of realism on the impression of artificial human faces. Presence, 16 (4): 337-351.

[31] Hanson, D. (2006). Exploring the aesthetic range for humanoid robots. [Proceedings of the ICCS/Cog Sci-2006 long symposium: Toward social mechanisms of android science, 39-42].

[32] Laue, C. (2017). Familiar and strange: gender, sex, and love in the uncanny valley. Multimodal Technologies and Interaction, 1-11.

[33] Pollick, F., Paterson, H., A, B., & Sanford, A. (2001). Perceiving affect from arm movement. Cognition, 82: 51-61.

[34] Mone, G. (2016). The edge of the uncanny scientists is learning more about what makes robots and chatbots engaging. Communications of the ACM. 59(9): 17-19

[35] MacDorman, K. F. YouTube - Charting the Uncanny Valley: Introduction (2007). http://www.youtube.com/watch?v=geF1XO5IPc8 (last accessed March 2, 2017)

[36] Bartneck, C., Kulić, D., Croft, E., & Zoghbi, S. (2009). Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. International Journal of Social Robotics, 1(1): 71-81.

[37] Sansoni, S., Wodehouse, A., McFadyen, A., & Buis, A. (2015). The aesthetic appeal of prosthetic limbs and the uncanny valley: the role of personal characteristics inattraction. International Journal of Design, 9(1): 67-81.

[38] Ho, C. C., MacDorman, K. F., & Pramono, Z. (2008). Human emotion and the uncanny valley: a GLM, MDS, and Isomap analysis of robot video ratings. In T. Fong, K. Dautenhahn, M. Scheutz, & Y. Demiris (Eds.), [Proceedings of the 3rd ACM/IEEE International conference on Human Robot Interaction, 169-176]

[39] Wang, S. Lilienfeld, S.O. & Rochat, P. (2015). The uncanny valley: existence and explanations. Review of General Psychology, 19 (4): 393– 407.

[40] Mitchell, W. J., Szerszen, S. A., Lu, A. S., Schermerhorn, P. W., Scheutz, M., & MacDorman, K. F. (2011). A mismatch in the human realism of face and voice produces an uncanny valley. I-Perception, 2(1): 10–12.

[41] Schein, C. & Gray, K. (2015). The eyes are the window to the uncanny valley. Mind perception, autism and the missing soul. Interaction Studies, 16(2): 173-179.

[42] MacDorman, K. F., Vasudevan, S. K., & Ho, C.C. (2009). Does Japan really have robot mania? Comparing attitudes by implicit and explicit measures. AI & Society, 23(4):485- 510.

[43] Iroju,O.G. (2014). Capacity building in electronic health in Nigeria healthcare delivery system. [Proceedings of 3rd Interdisciplinary International Conference, Center for Promotion for Educational and Educational Scientific Research, Nigeria].

[44] Ellis, H. D. & Lewis, M. B. (2001). Capgras delusion: a window on face recognition. Trends in Cognitive Sciences, 5(4): 149-156.

[45] Ellis, H. D., Whitley, J., & Luaute, J.P. (1994). Delusional misidentification: the three original papers on the Capgras, Fregoli and intermetamorphosis delusions. History of Psychiatry, 5(17):117–118.

[46] Solomon, S., Greenberg, J., Schimel, J., Arndt, J., & Pyszczynski, T. (2004). Human awareness of mortality and the evolution of culture. In M. Schaller & C. S. Crandall (Eds.), The psychological foundations of culture.

[47] Dillon, A. (2001). User acceptance of information technology. In Encyclopedia of Human Factors and Ergonomics.

[48] von der Pütten, R.(2014). Uncannily human. Experimental investigation of the uncanny valley phenomenon. PhD Dissertation, Universität Duisburg-Essen.

[49] Pino, M., Boulay, M., Jouen F., & Rigaud, A.S. (2015). Are we ready for robots that care for us? Attitudes and opinions of older adults toward socially assistive robots. Frontiers in Aging Neuroscience.

[50] Cabibihan, J.J., Carrozza, M. C., Dario, P., Pattofatto, S., Jomaa, M., & Benallal, A. (2006). The uncanny valley and the search for human skin-like materials for a prosthetic fingertip. [Proceedings of the 6th IEEE-RAS International Conference on Humanoid Robots, 474-477]

[51] Weiss, A. & Evers, V. (2011). Exploring cultural factors in human-robot interaction: a matter of personality? Comparative Informatics Workshop.